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ABSTRACT

A brief review of some of the more important needs imposed by current and projected Department of Defense training problems is followed by descriptions of such automated aids as the LAMPS MARK III Weapons System and the Air Force's F-16 Instructional System Development (ISD) effort. These aids have been designed and developed in response to the need for empirically tested instructional methods to train personnel to operate increasingly sophisticated and complex weapons systems. Also considered are recent developments in automated task analysis, objectives hierarchies, media selection, syllabus construction, and training support analysis, and implications for computer assisted instruction and computer managed instruction are discussed. (RAO)

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AN AUTHOR MANAGEMENT SYSTEM AND OTHER COMPUTER-BASED AIDS TO ISD

by

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Introduction

The principal thesis for this paper is that there is a significant and increasing need for automated support to the ISD process. The broad range of government and industrial participation in this symposium can be taken as one measure of this need, and the products and practice emerging from many recent government and industrial contractual activities can be utilized as a measure of both the state-of-the-art in computer aids to ISD and the important current trends in this emerging technology. This paper will briefly recapitulate some of the more important needs imposed by current and projected DOD training problems and will then describe several automated aids (both DOD and industrial proprietary) designed and developed in response to those needs. Several examples will be presented of the actual application and output of such aids in the ISD settings.

Needs and Problems

Trainers in ISD must deal with an increasingly complex DOD training problem. Weapons systems are becoming more complex and sophisticated. At the same time, technological acceleration in many fields has greatly increased the rate at which these systems are either outdated or significantly revised. In addition, in many areas the characteristics of personnel who must operate and maintain the systems has significantly and adversely changed from the past. The personnel who are called upon to operate and maintain these complex, sophisticated and ever-changing systems typically have less education than those available under the draft, and what they lack in education is seldom compensated for by experience, as turnover is frequently high. Meanwhile, the scope of formal training within DOD increases as programs are integrated into a continuum-of-training concept which is gradually replacing the myriad, independent, and often redundant, or incomplete ("Tower of Babel") smaller scope of training programs the trainee hitherto had to survive.

The response to these problems has been the development of systematic approaches to designing and developing training. There is an emerging technology of instruction which has made possible a gradual shift from the artistic approaches of the past through empirical, interim applications to a rapidly maturing analytic and prescriptive approach. Figure 1 elaborates slightly on this progression and a few of its advantages, disadvantages, and implications. One of the most significant implications of the analytic approach, to anyone who has worked on an ISD

ARTISTIC APPROACH	EMPIRICAL APPROACH	ANALYTICAL/PRESCRIPTIVE APPROACH
Offers free rein to "great" teachers	Can capitalize on what works.	Can capitalize on what works.
Occasional opportunities for efficiency or effectiveness of inspired approaches.	Can improve. Allows advantages of artistic approach.	Can also capitalize on research and on prediction of theoretical models as starting place in new situation.
Not reproducible.	Usually proceeds from weak or incomplete theoretical basis.	Systems models provide Gestalt into which subprocedures fit.
Cannot train for it.	Essentially trial and error.	Better definition possible of both procedures and products at all stages.
Not amenable to mass production.	Start from scratch in new situations or risk applying inappropriate solutions.	Detailed prescriptive "how" not just "what." Procedures can emerge which can be improved in effectiveness, efficiency, and economy.
No "leverage" of expensive expertise Not reliable	Dependent on evaluation results for process definition. Due to expense, this data is often (not always) collected at limited level of detail. Therefore, the description of procedures or products is usually at a high level of generality. Lack of detailed, prescriptive procedures.	Can be "trained" and job-aid supported. Allows more personnel assignment flexibility. Allows easier/quicker/more efficient training of personnel. Allows "leverage" of expert/expensive people. Allows more use of less expert or more specialized people. Allows better quality control. More "reliable" (predictable) training. With detailed procedures, more automated support possible. Needs more management to realize full advantages.

Figure 1

project, is the last one listed -- the analytic approach requires careful and expert management if it is to realize all its potential.

Automated Aids

There are an increasing number of efforts being undertaken both in DOD and industry to deal with the problem of managing large-scale sophisticated ISD activities and to automate or provide automated support tools for selected subprocedures within those ISD models being applied. The breadth of participation in this symposium is indicative of the wide interest and broad range of activity in the field, both in DOD and in industry. It is already to the point where it is impossible to even superficially explore the progress being made and the program/products available in a symposium such as this. However, I will explore briefly a few of the automated ISD processes and management tools developed and used by myself and my colleagues, as a representative, but by no means comprehensive, sample of the state of the art and current trends. These represent a mixture of DOD and proprietary products.

While the breadth of interest and number of current, ongoing activities in the area of automated aids to ISD is heartening, there is at least one serious problem yet to be overcome which will actually become more serious over time as the amount of work invested and the number of products developed increases. That is the problem of integration of the many on-line tools, aids, systems, and data bases. It would be unfortunate if large amounts of money and effort were invested in developing a series of incompatible, overlapping, and incomplete aids. What is needed is a systematically designed, integrated, generalizable, and flexible set of tools and aids which will 1) support the full range of ISD activity, 2) interact freely, and 3) mutually support each other in terms of efficiently using minimally redundant data bases and formats. Use of the same or similar data bases and formats will allow the easy utilization of the output of one subsystem as the input for succeeding subsystems in the ISD process. The advantages of such a systematically designed set of ISD aids is obvious. These advantages are simply those of any comprehensive, integrated system based on centralized planning, control, and development over the alternative of "incremental" systems which are assembled from bits and pieces designed, developed, and utilized in isolation from each other. For these reasons, high level functional specifications of computer aids to the entire ISD process are very important.

The aids which will be discussed in this paper can be described in the context of one such functional specification. In July, 1978, NAVTRAEQUIPCEN issued Technical Report NAVTRAEQUIPCEN 77-C-0018-1, "Functional Specifications to Computer Aided Training Systems Development and Management (CATSDM) Support Functions" (Hughes, O'Neal, Kearsley, O'Neal,

Fee, Rodi, & Hermanns, 1978)[1]. This report is a high level functional specification for a comprehensive, integrated set of automated subsystems, programs, and data bases to support the entire ISD process from initial analysis through final systems revision and update. As you know, it is possible to functionally describe complex systems with many different alternative representations. One level of description of the CATSDM system of programs is shown in Figure 2. The technical report itself goes into considerable descriptive detail of the subsystems outlined, the ISD applications they support, the aids and tools they provide, the data bases they require, and the many and complex interactions between the system components and users.

This discussion will deal at some level with 11 of the 25 subsystems in the CATSDM functional specification as seen in Figure 2. These, in turn, can be considered, for purposes of this discussion, to be further grouped, as indicated on the Figure, into four major groupings of subsystems.

Let us now look at some of the specific computer tools and aids developed and how they fit into the subsystems described in this Figure.

Recent Developments in Automating Task Analysis and Objectives Hierarchy

A partial set of computer aids has been developed and was recently employed in the task analysis and objectives hierarchy development for the Shipboard Operator and Maintenance tracks for the LAMPS MARK III Weapons System ISD effort. These aids consist of programs and data bases corresponding to some of those covered in subsystems 2 (Task Listings), 4 (Task Validation and Selection Program), and 5 (Objectives Hierarchy Development) in the CATSDM functional specifications. These aids consisted of elaborations and adaptations of existing proprietary programs of the contractor. They resulted in significant savings of time and money and considerable improvement of the product on several important characteristics in the first sets of deliverables produced (e.g., the task listing and objectives hierarchies and supporting documentation for the Shipboard Operator's tracks). The initial data base provided by the prime contractor on this activity consisted of approximately 900 important tasks for four positions in each of 6 major mission phases. One of the simplest of the supporting aids provided consisted of flexible and sophisticated data entry and retrieval programs. These programs were human engineered to facilitate the entry, retrieval, documentation and manipulation of the task analysis data base for a variety of purposes, including identification and cross-referencing of identical, similar, or overlapping tasks, and the linking of tasks to subtasks and/or objective hierarchy elements decomposed from higher order tasks. Using these aids, it was possible to build the entire task analysis data base (eventually documented in a 5000 page deliverable) in 6 man-days of secretarial effort, working from the task analysts' handwritten data forms.

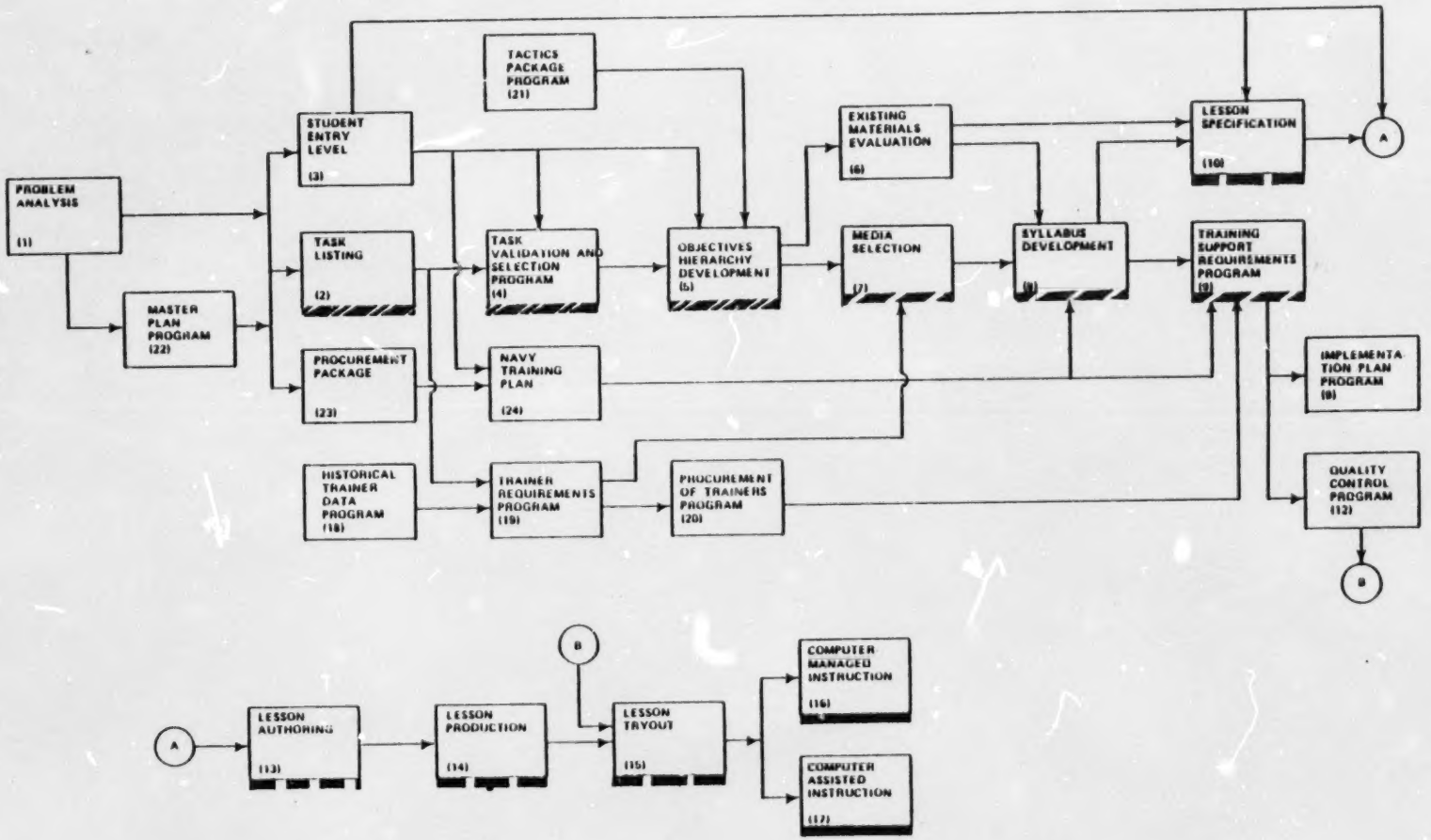

Figure 2: CATSDM System of Computer Programs – General FLOW Diagram (Process Monitoring Program Not Pictured Here Since It Tracks all Activities Shown)

This set of aids, while fairly straightforward and limited, provided a surprising and significant degree of leverage and flexibility to the professional staff on the project. For example, since manipulations were made on the automated data base, substantial revisions to the data base could be made on an ongoing basis. Such changes could be easily and quickly documented by periodic, formatted listings of the task elements and accompanying data to reflect historical stages in the development of the final, revised task analysis and objectives hierarchy. With the automated support, it was possible to build the initial data base, continually update it, and creatively manipulate it at extremely low cost, with very high frequency, and for the total duration of the project. That is, since the system could accommodate even massive changes in a very short time and immediately respond with updated reports and listings, there was no requirement for a premature "freeze" on further changes. Indeed, the data base was significantly updated and modified up to the last week of the reporting period for the deliverables involved.

This proved to be extremely advantageous in the case of the objectives hierarchies. On a previous project, of a roughly similar scope, the contractor had found it necessary, due to the extensive art, paste-up and production requirements of the objectives hierarchy documentation, to freeze the objectives hierarchy months before the delivery date. With the help of the on-line aids, the objectives hierarchies could be (and in some cases, were) modified up until moments before the start of the printout of the final project deliverable, much of which was in the form of the formatted listings, diagrams, cross-references, and indices generated by the computer. It is estimated that the nearly 5,000 pages of computer outputs would have cost in the neighborhood of $50,000 to generate by manual production efforts, and would have required a much earlier freeze of the data (meaning that the final product would have represented many fewer iterations of the initial data base), and the manually produced product would have been prey to a far greater number of errors and omissions, especially in the area of cross-references and indices which were generated automatically by the computer, but which would have been nearly impossible to generate accurately by manual cross-checking methods. These programs are being significantly improved, elaborated, and augmented to support even more of the effort in developing the remaining deliverables under this contract dealing with the Shipboard Maintenance task listings and hierarchies.

Recent Developments in Automating Media Selection, Syllabus Construction and Training Support Requirements Analysis

A significant set of automated aids and tools has recently been applied to the Air Force's F-16 ISD effort in the areas of media selection, syllabus development, and training support requirements analysis. The initial transformation of the basic

task analysis for the F-16 pilot generated approximately 800 criterion referenced objectives (CROs) which had to be converted into academics and hands-on objectives for syllabus purposes. Then these objectives had to be assigned appropriate implementation media designations for instructional development, syllabus, and training support requirements analysis purposes. After eliminating redundant, entry-level and non-critical elements, the academics objectives hierarchy decomposed into 696 instructional objectives, covering both the pilot course and the introductory instructor pilot course. It had been proposed to classify the academic objectives into instructional categories and to make generic media selections based on the strategy requirements for those categories for purposes of completing the complex media selection process within the limited constraints of the available project resources. With the support of automated aids, it was possible to refine this process and overcome its major deficiency; that is, regardless of instructional strategy, different objectives within any category may have widely divergent content and specific display requirements. Content and display requirements would significantly modify the generic media assigned to any specific objective within an instructional class.

With the on-line aid, it was possible to rate each of the 696 academic objectives in terms of 29 different display, response, analysis and feedback requirements. It was also possible to define the characteristics of each of 27 different media (the total media pool considered) on each of the 29 decision factors. It was then possible to perform the nearly 18,000,000 comparisons required and generate, for every objective, a list of all media which met minimum requirements for that objective in the critical areas; and further to assign an overall figure of merit to each of the acceptable media for the objective.

The initial data base was assembled by instructional personnel in approximately 3 man-weeks of effort and was entered on-line by a secretary in approximately 2 days. Each subsequent manipulation of that data base for different media mixes required approximately 1 1/2 minutes. It was, therefore, obviously possible to explore a wide variety of media mixes for purposes of determining their instructional adequacy and their training support requirements implications.

Similarly, from the same data base, it was possible to perform extensive cross-checks and modifications to the initial sortie syllabus. The Air Force had a preliminary definition of 76 training sorties, including which CROs were to be taught and/or evaluated on each. An independent data base was generated by the contractor consisting of subject matter experts' (SMEs')definition of the number of times a CRO should be practiced, the number of times and frequency with which it should be evaluated, and the amount of time required for each practice and/or evaluation. With this data base, it was possible to generate cross-checks of the validity of the preliminary sortie

definition. For example, it could be quickly determined which CROs were inadequately practiced, based on the SMEs' definition of the minimum practice requirements in the preliminary sortie definition. It could also be determined which sorties were significantly overpracticed and, hence, could be eliminated in the event available sortie time was exceeded. It was found that, indeed, in many cases, available sortie time (it was necessary to keep training sorties under 2 hours) was exceeded on many sorties, and other sorties, following the elimination of non-required CRO practice and/or evaluation, were only a few minutes long. With the on-line data base manipulation and comparison capabilities, it was possible to iterate sortie decisions and assignment until acceptable and optimal sortie syllabus definition was achieved.

In addition, it was possible to identify in which sortie each CRO was first practiced or required. This simplified the definition and scheduling of pre-sortie simulator and academic sessions, thereby completing the training syllabus. Again, these activities would have required many man-months of additional effort if done manually. Also, the exercise of generating these products with automated aids revealed significant errors and problems which would not have been identified using manual procedures until the program was well along, and often, not until training had actually begun.

Finally, with the help of rather straightforward computational programs, cost elements could be identified for all of the subsequent ISD design, development, implementation and evaluation activities for each major media mix and sortie configuration for training support requirements analysis purposes.

Another significant problem outlined in the earlier part of this discussion was the problem of managing large-scale, complex ISD efforts. Tracking the design, development, and production of multimedia, competency-based instructional materials, using differentiated staff models, in constrained cost environments on tight schedules can pose trememdous management problems. Defense Advanced Research Projects Agency (DARPA) has funded the development of a prototype management system to provide support on the ISD phases represented by subsystems 10 (Lesson Specification), 13 (Lesson Authoring), and 14 (Lesson Production) in the CATSDM model. This author management system has been developed and delivered in both the manual and automated version of DOD. The automated version was developed as a system of programs written in BASIC and implemented on the Wang 220-T minicomputer. Essentially, this management system allows flexible, project-specific definition of a project calendar, project personnel, course definition, and project task definitions. It will allow project staff to define start date, end date, holidays, and work days, and will then utilize this calendar in tracking products, making assignments, and making a variety of management projections to support critical decision

making throughout the life of the project. It will support and allow definition of project personnel, their skills, and their availability, and will track current assignments. It will support and allow the definition of the courses being worked on, the objectives, key words, media classifications, instructional classifications, prerequisite relationships, current design/development status, current course element related deadlines, and individual course element event hierarchies. The event hierarchy vector kept for each objective identifies that set of procedures, resources, personnel, and tasks uniquely required for each objective. The system manages these requirements, and from them it projects resources, time, and money required. The system will support and allow definition of a master list of design, development, and production events. It will cross-reference each of these critical events with the skills and resources required to complete the event. It will further cross-reference this data base with the amount of each skill (i.e., man-hours per event, per skill) or amount of critical resource required. In addition, it allows the definition of hierarchies of events, including prerequisite relationships, event flow, etc., which can then be assigned to appropriate course elements. The basic characteristics of the resulting system, both manual and automated, are shown in Figure 3. It is possible with the system to track ongoing assignments and to assign appropriate personnel, skills and resources to the individual design, development, and production events associated with each course element. It is also possible to make a variety of management projections based on changes in course structure, changes in personnel availability, and changes in the project design, development, and production procedures as reflected in the event hierarchy data base. Over 100 reports may be generated using the initial version of this management system. This system is more fully explained in Courseware's "Author Training Course/Author Management System Final Technical Report"; "Author Management Systems" (O'Neal & O'Neal, 1979)[2]; and (Faust & O'Neal, 1977)[3].

Finally, there are a variety of DOD and commercially available CAI/CMI capabilities emerging which are well documented in a voluminous and rapidly growing literature. The discussions of the strengths, weaknesses, economic feasibility, etc., of these systems are myriad and may be more or less known to the reader. However, for purposes of this discussion, one important implication of these emerging systems is significant. In general, as these systems become more and more sophisticated and comprehensive, they implicitly define larger and larger portions of the overall instructional and training development process. CMI systems may constrain and define more and more of the testing, tracking, evaluation data collection, and course structure definition activities. To the extent that these systems are easy to use, powerful, and widely applied, there will be an increasing tendency to accommodate ISD practice to their constraints as opposed to the more desirable condition of defining such systems on the basis of ISD requirements. This

AUTHOR MANAGEMENT SYSTEM AUTOMATED VERSION

- Form driven-minicomputer based.
- Allows each user to define task and personnel structures.
- Can be maintained and operated by managerial/secretarial personnel.
- Any report available within 15 minutes. (1000 objective course) 100 personnel.
- System "human engineered" using simple, well-defined, and documented procedures (flowcharts, checklists, etc.) and supported by on-line interactive protocols with many automatic error detection/reduction routines.
- Rich set of management/projection reports with very good modeling capability.
- Provides historical database for planning/auditing support.
- Model is "tuneable" to reflect current data and may be allowed to be automatically "self-tuning."

Figure 3

underscores the importance, then, for quickly replacing authoring "languages" with more generally applicable authoring "systems" based on an understanding of, and accommodation to, the requirements of emerging, complex, and sophisticated ISD models.

This discussion has obviously covered only a few of the many subsystems required to provide automated support to the full range of ISD activities; however, it is significant in that it has dealt with existing applications which have had significant impact in operational, DOD ISD activities. To the extent these, and many other currently emerging, on-line aids to ISD are designed, developed, and implemented in piecemeal fashion, the full value of systems such as those described by the CATSDM model may never be realized. Since the observed advantages of automated support to even small segments of the ISD process have been extremely great, centralization and coordination of the many separate efforts now ongoing would seem to be critically important to the continued development of ISD in meeting the somewhat intimidating training needs that lie before us.

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